EFFECT OF INTER-PLY SLIDING ON THE APPEARANCE OF DEFECTS FOR MULTILAYERED COMPOSITE SHAPING

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Abstract

The transport sector is one of the fastest growing consumer of energy and producer of greenhouse gases in the world. Consequently, transportation means with a low energy consumption, and thus global warming, are more and more demanding as being a major concern again the protection of the environment and hence respect a durable development. This aim can be achieved by reducing the mass of the transportation means and this by replacing metallic materials by composites ones on structural parts subjected to severe mechanical solicitations and this with equal mechanical performances. Indeed, composite materials are able to propose credible answers to the optimization of the thick structural parts with significant size through their good ratio strength/weight and especially their anisotropy which can be adapted to the mechanical solicitation of the structure.

To manufacture the composites pieces, the RTM is the more interesting process because it offers the best compromise in terms of repeatability, production rates and low final cost [une référence]. The first step of the process consists in draping a dry preform before injection of the liquid resin. This stage is a delicate phase and the mechanisms taking place are complex and different than the ones occurring during the stamping of metallic sheets. These mechanisms are far from being fully understood [1] which hampers the mastery of the manufacturing process and development of composite materials. In addition, the increasing use of materials with low environmental effect (biomaterials ...) and complex weaving architectures (interlock, 3D fabrics), makes it more difficult.

Many methods have been proposed recently to achieve representative sheet forming simulations of dry fabric, with different approaches [2-4]. These studies need several key entries such as the dry fabric mechanical properties and the fabric/tool friction coefficient, which have been widely studied [5-8]. When dealing with the multiply forming of composite thick parts, a significant relative sliding of the layers occurs [9]. This sliding generates fabric/fabric friction that has been recently studied [10, 11] and where the effect of woven meso-structure on the behavior has been highlighted. However, this relative sliding coupled with the phenomena that occur during the friction [11] can leads to the defects apparition or their amplification.

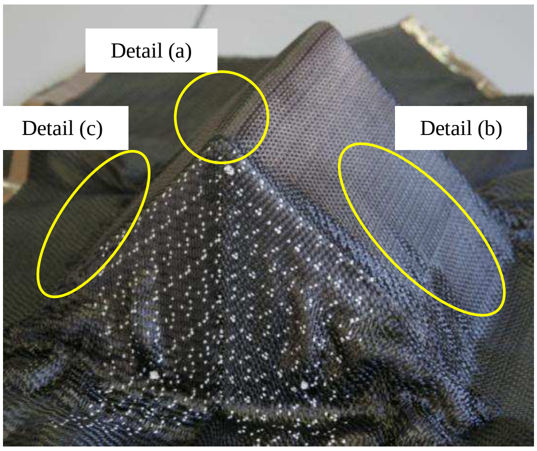
The aim of this study is then to investigate experimentally the effect of fabric/fabric friction behavior on defects apparition when dealing with multilayered shaping of composite dry fabric.

For this purpose, forming tests of interlock fabric (G1151) with prismatic punch were carried out on a specific device [12]. Tests conditions allowing defects apparition, such as wrinkles, in the useful areas of the shapes are used. Tests were realized with one layer and several layers of dry fabric with the same test conditions. Defects and shear angles were quantified in the useful shape areas (fig. 1) for each test then quantitative and qualitative comparisons were made between the different configurations.

These comparisons showed that the shear angles on different areas of interest are almost identical between the multilayered shapes and single-ply ones.

For defects, the locations of areas on which they appear are the same (fig. 1). However, the importance of each defect and the extent of the affected areas are more significant in the case of multilayered shapes. Additional defects, such as fiber breakage, were also observed in the same areas for this configuration. These measures and

observations carried out in this study highlight the effect of the fabric/fabric friction behavior and relative sliding between layers on the defects and their appearance.



Final prismatic shape

Detail (b) Fibre breakage   Detail (c) : wrinkle

Detail (d) buckle

Fig. 1. Multilayered prismatic shape with defects on the useful area.

References

[1] S. Hivet G., Allaoui S., Soulat D. Wendling A. Chatel "Analysis of woven reinforcement preforming using an experimental approach". *Proceeding of the 17th International Conference on Composite Materials*, Edinburgh, UK, 27 Jul-31 Jul 2009.

[2] K. Vanclooster, S. Lomov, and I. Verpoest Simulation of multi-layered composites forming. *International Journal of Material Forming*, Vol3, pp695–698, 2010.

[3] R.H.W. ten Thije, R. Akkerman, and J. Huétink. "Large deformation simulation of anisotropic material using an updated lagrangian finite element method". *Computer Methods in Applied Mechanics and Engineering*, vol 196(33-34), pp3141–3150, 2007.

[4] N. Hamila and P. Boisse "A meso macro three node finite element for draping of textile composite performs". *Applied Composite Materials*, vol 14, pp235–250, 2007.

[5] J. Launay, G. Hivet, A.V. Duong, and P. Boisse "Experimental analysis of the influence of tensions on in plane shear behaviour of woven composite reinforcements". *Composites Science and Technology*, vol 68(2), pp506–515, 2008.

[6] E. de Bilbao, G. Soulat, D. Launay, J. Hivet, A. Gasser "Experimental study of bending behaviour of reinforcements". *Experimental Mechanics*, vol 50(3), pp333–351, 2010.

[7] J. Cao, R. Akkerman, P. Boisse, J. Chen, H.S. Cheng, E.F. de Graaf, J.L. Gorczyca, P. Harrison, G. Hivet, J. Launay, W. Lee, L. Liu, S.V. Lomov, A. Long, E. de Luycker, F. Morestin, J. Padvoiskis, X.Q. Peng, J. Sherwood, Tz. Stoilova, X.M. Tao, I. Verpoest, A. Willems, J. Wiggers, T.X. Yu, and B. Zhu "Characterization of mechanical behavior of woven fabrics: Experimental methods and benchmark results". *Composites Part A*, vol 39(6), pp1037–1053, 2008.

[8] P. Badel, E. Vidal-Sallé, P. Boisse "Computational determination of in-plane shear mechanical behaviour of textile composite reinforcements". *Computational Materials Science*, vol 40(4), pp439–448, 2007.

[9] S. Bel, N. Hamila, P. Boisse, F. Dumont, "Finite element model for NCF composite reinforcement preforming: Importance of inter-ply sliding". *Composites: Part A*, vol 43, pp2269–2277, 2012.

[10] G. Hivet, S. Allaoui, B.T. CAM, P. Ouagne, D. Soulat "Design and potentiality of an apparatus for measuring yarn/yarn and dry fabric/dry fabric friction". *Experimental Mechanics*, Vol 52 (8), pp1123-1136, 2012.

[11] S. Allaoui, G. Hivet, A. Wendling, P. Ouagne, Soulat "Influence of the dry woven fabrics meso-

structure on fabric/fabric contact behavior". *Journal of Composite Materials*, Vol 46(6), pp627-639, 2012.

[12] D. Soulat , S. Allaoui, S. Chatel, «Experimental device for the performing step of the RTM process», *International Journal of Material Forming*, Vol 2 (1), pp181-184, 2009.